U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-260 093

A LIMNOLOGICAL INVESTIGATION OF THE YELLOWSTONE RIVER RELATED TO TASTE AND ODOR PROBLEMS IN DOMESTIC WATER SUPPLIES, LAUREL TO GLENDIVE, MONTANA, AUGUST-SEPTEMBER, 1952

PUBLIC HEALTH SERVICE, KANSAS CITY, MISSOURI

SEPTEMBER 1952

PB 260 093

A LIMNOLOGICAL INVESTIGATION OF THE YELLOWSTONE RIVER RELATED TO TASTE AND ODOR PROBLEMS IN DOMESTIC WATER SUPPLIES, LAUREL TO GLENDIVE, MONTANA, AUGUST-SEPTEMBER, 1952

U.S. DEPT. OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
MISSOURI DRAINAGE BASIN OFFICE

287039

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No. PB-260 093
4. Title and Subtitle A Limnological Investigation of the Yellowstone River Related to Taste and Odor Problems in Domestic Water Supplies, Laurel to Glendive, Montana, August-September, 1952			5. Report Date Sep 52 6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Public Health Service, Kansas City, Mo. Missouri Drainage Basin Office			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts Causes of tastes and odors that have frequently been reported in water supplies taken from the Montana stretch of the Yellowstone River in autumn were investigated in field studies concerned mainly with the river stretch from Laurel to Glendive, Montana. Sampling was conducted at eight locations along this section of the main stem and in the lower reaches of three tributaries. Data are reported for pollution discharges, chemical features, and biological features, including bottom organisms, algae, and plankton. Entrance of organic pollution was chemically detectable but nowhere did it greatly impair domestic water quality at the times of this investigation. A large role in abatement of pollution effects must be ascribed to life processes of benthic and plankton algae, since their influences upon stream chemistry were quite marked.

17. Key Words and Document Analysis. 17a. Descriptors

17b. Identifiers/Open-Ended Terms

Yellowstone River
Montana
*Water pollution sampling
*Stream pollution
Tables (Data)
Algae
Primary biological productivity
Rivers
Stream flow
Aquatic ecosystems
*Odors

17c. COSATI Field/Group 13B

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 32
	20. Security Class (This Page UNCLASSIFIED	22. Price

ATTENTION

AS NOTED IN THE NTIS ANNOUNCEMENT,
PORTIONS OF THIS REPORT ARE NOT LEGIBLE.
HOWEVER, IT IS THE BEST REPRODUCTION
AVAILABLE FROM THE COPY SENT TO NTIS.

A LIMNOLOGICAL INVESTIGATION OF THE YELLOWSTONE RIVER RELATED TO TASTE AND ODORS PROBLEMS IN DOMESTIC WATER SUPPLIES, LAUREL TO GLENDIVE, MONTANA, AUGUST-SEPTEMBER, 1952

This investigation, aimed at determining causes of tastes and odors which have frequently been reported in water supplies taken from the Montana stretch of the Yellowstone River in autumn, was planned to include studies prior to and during a period of taste and odor occurrence. However, no problems of significance occurred in 1952, and the following account represents only the first phase of the study--stream conditions that did not produce objectionable domestic water quality.

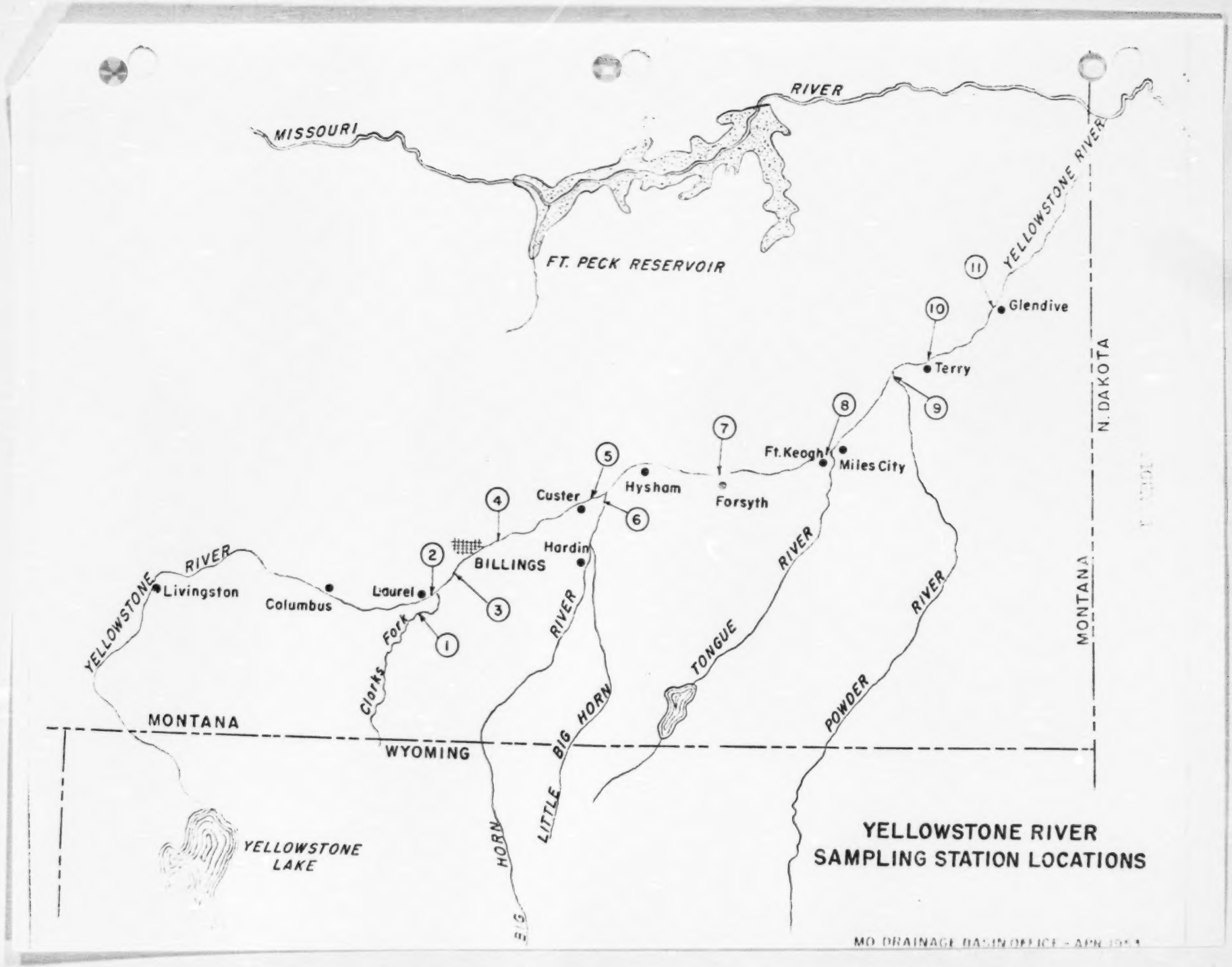
Field studies covered the periods August 18-22 and September 23-25, 1952, inclusive, and were mainly concerned with the river stretch from Laurel to Glendive, Montana. Sampling was conducted at 8 locales along this section of the main stem and in the lower reaches of 3 tributaries. Features of each of these 11 sampling stations appear in Table 1, and their locations are shown in Figure 1. Bottom organisms were collected in the Yellowstone a few miles below Livingston, Montana.

Physical Features

The Yellowstone River emerges from the mountains near Livingston, and then courses through plains and some low hills to its junction with the Missouri (Figure 1). Average slope in the mountains is greater than 30 feet per mile but slope in the stretch studied is approximately 7.2 feet per mile. Here the river lies in a wide, sparsely wooded valley where shading of water is negligible. Clarks Fork (Figure 2) and the Yellowstone above Billings consisted of alternating riffles and pools. Long smooth stretches occupied the greater portion of the Yellowstone

Table 1. General stream features at each sampling station

Sta. No.	Stream and name location	Approx. river mi. above mouth	Type situation	Bottom materials	Approx. greatest depth	Approx. discharge c.f.s.
1	Clarks Fork 5 miles south of Laurel, Mont.	2.5	Riffles and pools	Rock, gravel, and sand	4'	8-18-52 789 9-28-52 295
2	Yellowstone River at Laurel, Mont	366.5	Riffles and pools	Rock and gravel, some sand	10'	-
3	Yellowstone River above Billings, Mont.	349	Riffles and pools	Rocks and sand	8'	8-19-52 5730 9-23-52 3090
4	Yellowstone River at Huntley, Mont.	335	Smooth stretch	Rocks and sand with oily tar	7'	-
5	Yellowstone River near Custer, Mont.	285	Smooth stretch	Rocks, sand, and mud	8'	-
6	Big Horn River at Big Horn, Mont.	1	Smooth stretch	Sandy	9'	8-21-52 2130 9-26-52 2340
7	Yellowstone River at Forsyth, Mont.	231	Smooth stretch	Rocks, Sand, and mud	10'	-
8	Yellowstone River at Ft. Keogh, Mont.	179	Smooth stretch	Rocks and sand	8'	8-22-52 7320 9-28-52 5610
9	Powder River 12 miles west of Terry, Mont.	0.5	Riffle	Sand and gravel	1.5'	-
10	Yellowstone River below Terry, Mont.	133	Smooth stretch	Rocks and mud	10'	-
11	Yellowstone River at Glendive, Mont.	92.5	Smooth stretch	Rocks and sand	9'	-



MO DRAINAGE BASIN OFFICE - APR 1974

Fig. 2. Clarks Fork at Station 1

below Billings (Figure 3). The lower stretch of the Big Horn (Figure 4) was a smoothly flowing stretch, and the lower Powder River was reduced to a shallow creek occupying a narrow strip of a wide sandy stream bed. Alkali deposits were common along the banks of the lower Yellowstone and tributary streams in the same region. Stream bottoms were composed of rocks, gravel, sand, and mud, with finer materials becoming more prominent in lower reaches. The Yellowstone (excepting certain short reaches receiving irrigation returns) and all tributaries except the Big Horn were quite clear during the periods of study. Turbidity of the Big Horn amounted to approximately 50 ppm. Temperature, which varied noticeably with time of day when measured, ranged from 14.5 to 25.5 degrees centigrade.

Fig. 3. Yellowstone River at Station 10

Pollutional Discharges

Sources of pollution in the Yellowstone Basin appear in Public Health Service Publication 129, Yellowstone River Drainage Basin, A Co-operative State-Federal Report on Water Pollution, January, 1952, and are not listed here. Some influences of pollution noted during this study were: (1) sulfur deposits below cooling water discharge from an oil refinery at Laurel; (2) oil and tar bottom deposits below Billings; (3) increased turbidity of segments of the Yellowstone River due to returns of irrigation water; (4) oily odor in water below oil separator outfalls; and (5) organic sludge deposits below Glendive.

Chemical Features

Results of chemical analyses appear in Table 2 and Figure 5. Water chemistry indicated the entrance of organic pollution at certain localities and an intense rate of photosynthesis at all localities. Pollutional impairment of water quality was not severe at the times of this investigation, and it seems reasonable to assume that some undesirable pollutional influences were abated by the effects of photosynthesis. Fecal contamination was indicated at Billings, Forsyth, Miles City, Terry, and Glendive in August, and at Billings and Forsyth in September, by the presence of nitrite nitrogen. Nitrite occurrence in lower Clarks Fork in September possibly represented local livestock influences, since plankton at that locality was not of the type or stage to produce nitrite in the stream, and this substance could hardly be expected to persist all the way down from upstream sewered communities.

Fig. 4. Big Horn River at Station .

Table 2. Chemical features of the Yellowstone and lower reaches of certain tributaries

Station, time, and date	Temp. °C	pH	CO_3 Alk. ppm.	HCO_3 Alk. ppm.	O_2 Pct. Sat.	PO_4 ppm.	NH_3-N ppm.	NO_2-N ppm.	NO_3-N ppm.
2:05 pm.									
1 (8-18-52)	23.5		30.2	238.5	150	3.0	-	0.0	
8:30 am.									
2 (8-19-52)	17		10.1	144.4	118	1.0	-	0.0	
11:15 am.									
3 (8-19-52)	17.5		16.8	168	138	1.0	-	0.0	
3:45 pm.									
4 (8-19-52)	22		16.8	178	130	1.0	-	0.007	
10:15 am.									
5 (8-21-52)	22		20.1	184.8	125	1.0	-	0.005	
Big Horn Riv.									
11:30 am.									
6 (8-21-52)	22.5		30.2	275.5	140	3.0	-	0.0	
2:45 pm.									
7 (8-21-52)	24		23.5	208	145	1.0	-	0.005	
4:00 pm.									
8 (8-22-52)	25.5		30.2	215	138	1.0	-	0.005	
9:00 am.									
10 (8-22-52)	23.5		20.1	221	118	2.0	-	0.005	
12:30 pm.									
11 (8-22-52)	24		20.1	218	120	1.0	-	0.005	
10:00 am.									
1 (9-23-52)	14.5	8.3	8.0	347	118	1.0	0.7	0.0075	0.7
11:00 am.									
2 (9-23-52)	16	8.3	10.0	169.5	122	1.0	0.9	0.0	0.05
2:30 pm.									
3 (9-23-52)	20	8.5	21	185.5	147	1.0	0.25	0.0	0.05
4:00 pm.									
4 (9-23-52)	19	8.5	25	193	150	1.0	1.1	0.0025	0.15
1:00 pm.									
5 (9-24-52)	20	8.7	38	190	145	1.0	0.9	0.005	0.05
Big Horn Riv.									
2:00 pm.									
6 (9-24-52)	21.5	8.5	14	268	130	1.0	0.9	0.0	0.2
4:20 pm.									
7 (9-24-52)	22	8.5	20	225	140	0.5	0.7	0.0075	0.05
8:40 am.									
8 (9-25-52)	16.5	8.5	14	221.5	115	0.0	1.1	0.0	0.05
11:00 am.									
9 (9-25-52)	18.5	8.4	21	303	125	0.1	0.9	0.0	0.05
1:30 pm.									
10 (9-25-52)	21	8.5	22	223	125	0.05	1.1	0.0	0.0
3:20 pm.									
11 (9-25-52)	21	8.5	16	235	130	0.05	0.5	0.0	0.05

Phosphate, a compound of major influence in promotion of algal and other plant growth, was present in significant quantities at all stations at all times sampled except Station 3 on September 25. Ammonia and nitrate nitrogen were not above levels that have been observed in some unpolluted streams in the Missouri Basin. Supersaturated oxygen, high pH and monocarbonate alkalinity levels resulted from photosynthesis. Mineral content as measured by bicarbonate alkalinity showed a progressive downstream increase in the Yellowstone that was augmented by tributary discharge of more mineralized water.

Biological Features

Bottom Organisms (Benthos)

Available sampling methods did not allow accurate quantitative estimation of bottom organisms in the Yellowstone River below Billings. Rocky river bottom permitted dredging only in selected spots at each station, and depth of water was too great for unit hand net collection. Dredging and marginal hand net sampling were conducted along lower reaches of the stretch investigated, but it is not believed that these methods disclosed all types of bottom organisms present.

Bottom fauna of the Yellowstone below Livingston, Montana, consisted chiefly of caddis larvae and stonefly nymphs, with some mayfly nymphs and midge fly (chironomid) larvae. Caddis worms and stoneflies were very, very thickly concentrated. Much the same type of population existed at Stations 1 and 3, although concentrations were only a fraction as great. Organisms recovered by dredge sampling at each station are shown in Table 3. It is apparent that the dredge was incapable of recovering all types of organisms existing at Station 3 and no greater accuracy may be

Table 3. Bottom organisms recovered from dredge samples. Numbers represent concentration per square foot

	Stations										
	1	2	3	4	5	6	7	8	9	11	
Ephemeroptera											
Tricorythodes sp.	3					2					Mayfly
Trichoptera											
Cheumatopsyche sp.	7					5			3		Caddis fly
Diptera											
Chironomidae											
Spaniotoma sp.	11										Midge fly larvae
Pentaneura flavifrons		17									
Metriocnemius sp.			2		19						
Tanytarsus sp.					13						
Tendipes stylifera	2		2								
Tendipes militaris			27						11		
Tendipes flavicingulus							14				
Tendipes quadripunctatus							2				

No Organisms

Sample decomposed - Remnants of Chironomidae

Sample totally decomposed

ascribed to its use at other stations where organisms were present. The dearth of benthos indicated by dredge samples at Station 4 was confirmed by marginal sampling. Absence of bottom fauna in this region apparently results from toxic refinery wastes and oily bottom deposits. Hand net collections from stream margins at Stations 6, 7, 8, and 10 all contained water boatmen (Hemiptera, Corixidae), water beetles (Coleoptera, Dytiscidae), mayfly nymphs (Tricorythodes), caddis larvae, dragon fly nymphs, and stonefly nymphs.

Bottom Algae (Periphyton)

Benthic algal growths were common. In some regions (Stations 1, 2, 3 and 4) the bulk of such vegetation consisted of Cladophora, a branched filamentous green alga, and diatoms, while in other areas (Stations 5, 6, 7, 8 and 10) diatoms formed the greater part of the benthic plant cover. In lower reaches (Stations 6, 7, 8 and 10) mats of the blue-green alga Phormidium grew at the water line.

Currents constantly eroded benthic algae and their components were present in suspension at all stations. Suspended microorganisms of benthic origin may be regarded as accidental or facultative planktors, but in many streams, and the Yellowstone is no exception, they at times make up the bulk of the plankton. Bottom inhabiting diatoms appeared prone to displacement by water movement, while filamentous blue-green and green algae were uncommon in plankton samples. The marginal Phormidium growths broke loose as discs a few centimeters in diameter which apparently did not undergo extensive fragmentation as they floated downstream on the surface. Both living and dead specimens of benthic algae appeared in the plankton, and dead ones often outnumbered living

Table 4. Yellowstone River Plankton, August, 1952. Numbers represent concentration per lit

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	St
BLUE-GREEN ALGAE						
Nostoc Gr.	3,348					
Oscillatoria Gr. (Includes Phormidium)			1,674	6,696		
Chroococcus sp.*		4,960				
Gomphosphaeria sp.*						1
DIATOMS						
Cyclotella) Gr.*	1,674			1,674		4
Stephanodiscus)	1,674			[illegible]	40,176	62
Melosira sp.*	1,674			1,674		1
				3,348	4,960	53
Rhizosclenia sp.	1,674	1,674	3,348		3,348	1
		8,388			3,348	2
Diatoma sp.	20,088	65,224	77,004	80,352	25,048	4
	1,674		1,674	4,960		1
Synedra spp.	10,044	15,004	13,392	11,656	[illegible]	10
	16,740	28,396	30,823	25,180	134,008	598
Fragilaria crotonensis*						13
						251
Asterionella formosa*			1,674	1,674		1
Tabellaria sp.	3,348	4,960	6,696	8,368	1,674	
	1,674	3,348	1,674		1,674	

, August, 1952. Numbers represent concentration per liter

Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta.10	Sta.11
3,348									
dium)		1,674	6,696					3,348	
	4,960					1,674	13,392		
					1,674				
1,674 1,674			1,674 [illegible]	40,176	4,960 62,000	1,674 80,352	16,740 837,000	3,348 16,740	
1,674			1,674 3,348	4,960	1,674 53,568	1,674 15,004	1,674 23,436	16,740	
1,674	1,674 8,368	3,348		3,348 3,348	1,674 3,348	1,674 10,044	3,348 66,960	1,674 36,828	
20,088 1,674	65,224	77,004 1,674	80,352 4,960	25,048	4,960 1,674	18,352	15,092 1,674	25,048 4,960	
10,044 16,740	13,004 28,396	13,392 36,823	11,656 55,180	23,008 134,008	10,044 596,160	4,960 254,443	10,044 509,223	2,348 320,104	
					13,392 251,100	3,348 63,612	15,004 113,952	11,656 23,436	
		1,674	1,674		1,674	1,674	1,674		
3,348 1,674	4,960 3,348	6,696 1,674	3,348	1,674 1,674		3,348	1,674	2,348	

Table 4. Yellowstone River Plankton, August, 1952. Numbers represent concentration per 1

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	
DIATOMS (cont'd.)						
Gyrosigma sp.	1,674	1,674				
Navicula Gr.	296,236 136,152	361,584 179,056	388,368 232,844	435,240 274,536	195,796 83,700	1 1
Amphora sp.	9,176 9,176	3,348 13,392	6,696 3,348	4,960 6,696	3,348 1,674	
Cymbella spp.	18,352 16,740	20,038 13,392	23,436 26,784	31,744 13,392	13,392 1,674	
Rhopalodia sp.	1,674 1,674					
Cystopleura sp.		1,674	1,674	1,674 1,674		
Gomphonema Gr.	41,738 31,744	78,616 31,744	83,700 46,872	88,680 25,048	73,656 28,396	
Nitzschia Gr.	24,676 21,700	169,012 43,524	169,012 73,656	194,184 70,308	51,832 25,048	
Surirella sp.	9,176 6,696	4,960 3,348	13,392 4,960	4,960 6,696	21,700	
GREEN ALGAE						
Oocystis sp.*		1,674			1,674	
Sphaerocystis sp.*						
Chlamy Lomonas Gr.*	1,674	6,696	1,674	6,696	1,674	

on, August, 1952. Numbers represent concentration per liter (cont'd.)

Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 10	Sta. 11
1,674					1,674		272	558	
	1,674				1,674	1,674	272	1,116	
296,236	361,584	388,368	435,240	195,796	164,052	177,444	297,972	220,968	
136,152	179,056	232,844	274,536	83,700	133,920	93,744	97,092	83,700	
9,176	3,348	6,696	4,960	3,348		1,674	1,674	3,348	
9,176	13,392	3,348	6,696	1,674			1,674		
18,352	20,088	23,436	31,744	13,392	8,308	11,656	15,004	23,436	
16,740	13,392	26,784	13,392	1,674	6,696	3,348	4,960	3,348	
1,674									
1,674									
	1,674	1,674	1,674						
			1,674						
41,792	78,616	83,700	88,660	73,656	30,132	43,524	41,780	46,872	
31,744	31,744	46,872	25,048	28,396	10,044	11,656	4,960	6,696	
24,676	169,012	169,012	194,184	51,832	43,524	83,700	90,396	60,264	
21,700	43,524	73,656	70,368	25,048	97,092	33,480	97,092	157,356	
9,176	4,960	13,392	4,960		11,656	16,740	20,088	16,740	
6,696	3,348	4,960	6,696	21,700	18,352	10,044	6,696	15,004	
	1,674			1,674					
						1,674	6,696	4,960	
1,674	6,696	1,674	6,696	1,674	21,700	25,048	147,312	23,436	

Table 4. Yellowstone River Plankton, August, 1952. Numbers represent concentration per lit

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	St
GREEN ALGAE (cont'd.)						
Pediastrum Duplex						
Scenedesmus Limorphus				1,674	2,930	1
Scenedesmus Bijuga	1,674				2,930	
Closteriopsis Longissima Tropica*	3,348		1,674	1,674		
Ankistrodesmus Falcatus*	1,674		3,348	6,696	3,348	
Schroederia Setigera*			1,674	1,674	1,674	130
Lagerheimia sp.					1,674	
Actinastrum Hantzschii Fluviatile*						1
Tetrastrum Staurogeniaeforme						
Cosmarium sp.						1
EUGLENOPHYCEAE						
Trachelomonas sp.	3,348				3,348	
Euglena sp.	4,960	1,674	4,960			
DINOPHYCEAE						
Ceratium Hirundinella*						1
Total Living Organisms	267,344	342,360	500,340	490,296	385,610	1,39

sp. - 1 undetermined species.
spp. - 2 or more undetermined species.
Gr. - Group of species or closely related genera not identifiable at magnification

Underlined numbers indicate dead organisms.

n, August, 1952. Numbers represent concentration per liter (cont'd.)

	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 10	Sta. 11
						620	1,674	4,191	15,004	
				1,674	2,930	1,674	3,348		6,696	
	1,674				2,930		3,348	16,740		
*	3,348		1,674	1,674						
	1,674		3,348	6,696	3,348		1,674	18,352	11,656	
			1,674	1,674	1,674	130,572	93,744	157,356	60,264	
					1,674			1,674		
e*						1,674	3,348	15,004	4,960	
								3,348		
						1,674			1,674	
	3,348				3,348			4,960	3,348	
	4,960	1,674	4,960				4,960	4,960	3,348	
								272	272	
						1,116		553		
	267,344	342,660	500,340	490,296	385,610	1,398,006	719,572	2,241,113	832,722	

Sample decomposed in transit

es.
ed species.
closely related genera not identifiable at magnification used for counting.
ndicate dead organisms.

examples of the same group. Diatoms, for example, was a very abundant diatom on the stream bottom, yet only its dead individuals attained any significant concentration in the plankton. Dead examples of the Navicula group, another common constituent of the bottom growths, in many instances outnumbered its living representatives in the plankton, (Tables 4 and 5). The ratio between living and dead examples of various displaced groups may indicate variation in ability to survive conditions of the plankton environment or differences in erosion rate between living and dead organisms.

Plankton

Qualitative and quantitative aspects of river plankton appear in Tables 4 and 5. Figure 5 superimposes September plankton densities upon water chemistry. The majority of suspended organisms were displaced benthic forms, but true plankters (indicated by asterisks in the tables) were well concentrated in some reaches. The tables differentiate between organisms that were alive or dead at time of collection, and it may be noted that in several instances dead organisms carried in suspension were more numerous than living examples of the same groups. In most cases this state of affairs characterized displaced benthic groups and not true plankton organisms.

Concentration of suspended organisms during both sampling periods may be regarded as dense. Photosynthetic activity of plankton and benthic algae markedly modified stream chemistry and so produced high oxygen levels in all reaches.

The Big Horn River plankton population differed noticeably from that of the Yellowstone. Most Big Horn plankton organisms survived their

Table 5. Yellowstone River Plankton, September, 1952. Numbers per liter at each station

	Sta. 1 Clarks Fork	Sta. 2 Yellow-stone River	Sta. 3 Yellow-stone River	Sta. 4 Yellow-stone River	Sta. 5 Yellow-stone River	Sta. 6 Big Horn River	S Y s R
[illegible]							
Aphanocapsa sp.*	400	1,200	600	200	1,400		
Anacystis-Coelosphaerium*					800	200	
[illegible]							
[illegible]atoria gr.	800	200			1,200	200	
[illegible]	200						
[illegible]							
[illegible] sp.a*	800	1,000	800	600	400	11,000	
[illegible] sp.b*		200			400		
[illegible]-Stephano Discus gr.*	200			200	200	2,000	
[illegible]plania sp.	1,000	800	200	1,000	8,000	6,000	
[illegible]aria rotenensis*						2,200	
[illegible]lla formosa*						200	
[illegible] gr.			26,000	23,000	20,000	3,000	
	13,000	35,000	28,000	25,000	7,000	21,000	2
[illegible]tocis sp.		200					
Fragilaria sp.	22,000	59,400	57,600	67,000	19,000	8,000	
	1,000	9,400	5,400	5,400	200	200	
Navicula gr.	24,000	5,400	23,000	30,000	96,000	8,000	2
	63,000	54,000	48,000	177,000	194,000	32,000	3
[illegible]lla gr.	43,000	24,300	27,000	25,000	19,000	3,000	
[illegible]rora sp.					200		
[illegible] sp.							
Synedra sp.				200			
	3,000	600	800	1,000	1,800	3,400	
Cosmarium gr.	2,200	20,000	12,400	29,800	3,200	[illegible]	
Gymnozyga sp.		4,200	2,600	2,800	1,800		
[illegible]ospira sp.		200		200	200	200	
[illegible]tacum gr.	200	600				200	
[illegible]tophora Nolae							
[illegible]ceae sp.						200	

1952. Numbers per liter at each station

Sta. 2 Yellow-stone River	Sta. 3 Yellow-stone River	Sta. 4 Yellow-stone River	Sta. 5 Yellow-stone River	Sta. 6 Big Horn River	Sta. 7 Yellow-stone River	Sta. 8 Yellow-stone River	Sta. 9 Powder River	Sta. 10 Yellow-stone River	Sta. 11 Yellow-stone River
1,200	600	200	1,400		200	200		400	4,000
			800	200	600	1,200		800	800
							1,000		600
200			1,200	200		200	200	600	200
					200				400
1,000	800	600	400	11,000	7,000	12,000	200	3,000	19,000
200			400					200	200
		200	200	2,000	1,600	5,400	600	7,000	5,000
800	200	1,000	8,200	6,000	2,800	2,600	600	6,000	16,000
				2,200	1,200	5,400	200	3,000	8,000
				200	600	1,600		5,000	6,000
	26,000	23,000	20,000	3,000	4,000		600		5,000
35,000	28,000	25,000	7,000	21,000	20,000	60,000	22,000	41,000	41,000
200									
29,400	27,200	87,000	19,000	8,000	7,000	7,000		3,000	2,000
9,400	5,400	5,400	200	200					
5,400	23,000	50,000	96,000	8,000	22,000	13,000	200	8,000	2,000
54,000	45,000	177,000	194,000	32,000	30,000	23,000	600	7,000	32,000
24,300	27,000	25,000	19,000	3,000	7,000	8,000		1,200	1,400
			200						
						400			
		200							
600	800	1,000	1,800	3,400	2,400	4,200	200	5,000	5,000
20,000	12,400	29,800	3,200	800	1,200	1,200	200	2,000	600
4,200	2,600	2,800	1,800		400				
200		200	200	200					
600				200	600	1,400		1,000	800
						200			
				200		200			

Table 5. Yellowstone River Plankton, September, 1952. Numbers per liter at each station (cont'd.)

	Sta. 1 Clarks Fork	Sta. 2 Yellow-stone River	Sta. 3 Yellow-stone River	Sta. 4 Yellow-stone River	Sta. 5 Yellow-stone River	Station 6 Big Horn River
GREEN ALGAE						
Chlamydomonas gr.	800	1,200	800			
Gloeocystis sp.*					1,600	
Sphaerocystis sp.*						
Ulothrichales					200	
Scenedesmus bijuga	200					400
Scenedesmus quadricauda		400				
Scenedesmus dimorphus Alternans					200	
Chlorococcales						
Ankistrodesmus falcatus*		200		200		400
Ankistrodesmus H. pluvialis*						
Ankistrodesmus A. Tropica*						
Closterium Cambricum						
Desmidiales						
Desmidiales sp.						
Staurastrum sp.*					200	
Staurastrum sp.						400
	200	1,000	1,600	600	8,000	800
Closterium sp.	800			200		
Cosmarium sp.				200		
Euglena sp.	600	200	200	200	800	
Euglena viridis	200					
Phacus sp.		200				200
Trachelomonas volvocina						
Trachelomonas hispida						
Peridinium sp.					200	
Peridiniales	200			200		400
Synedra acus						
Synedra ulna	200	1,600	2,600	200	800	3,400
Synedra ulna var. danica						
Synedra ulna var. biceps						
Synedra ulna var. amphirhynchus						
Synedra ulna var. contracta						
Synedra ulna var. oxyrhynchus						
Synedra ulna var. subaequalis						
Synedra ulna var. splendens						
Synedra ulna var. vitrea						
Synedra ulna var. amphirhynchoides						
Synedra ulna var. longissima						
Synedra ulna var. spathulifera						
Synedra ulna var. aequalis						
Synedra ulna var. oxyrhynchoides						
Synedra ulna var. recta						
Synedra ulna var. contracta						
Synedra ulna var. danica						
Synedra ulna var. biceps						
Synedra ulna var. amphir

1952. Numbers per liter at each station (cont'd.)

Sta. 2 Yellow-stone River	Sta. 3 Yellow-stone River	Sta. 4 Yellow-stone River	Sta. 5 Yellow-stone River	Station 6 Big Horn River	Sta. 7 Yellow-stone River	Sta. 8 Yellow-stone River	Sta. 9 Powder River	Sta. 10 Yellow-stone River	Sta. 11 Yellow-stone River
1,200	800				1,200	3,000	1,200	13,000	11,000
			1,600			1,200	400	7,200	3,600
									800
			200						
				400	600	400		200	400
									200
400							200	200	400
			200		200	200		200	400
200		200		400	1,200	200		200	200
					200		7,000		200
						600		400	1,000
						200			200
								200	
									200
			200				200		
				400					
1,000	1,600	600	8,000	800	1,000	5,400		7,000	5,000
		200			200	200			200
		200							
200	200	200	800		600	400			
200				200		200	400		
							800	600	200
							800		
			200						
		200		400		200			
1,600	2,600	200	800	3,400	800	1,800	1,600	800	1,000

Table 5. Yellowstone River Plankton, September 1952. Numbers per liter at each station (cont'd.)

	Sta. 1 Clarks Fork	Sta. 2 Yellow-stone River	Sta. 3 Yellow-stone River	Sta. 4 Yellow-stone River	Sta. 5 Yellow-stone River	Sta. 6 Big Horn River
PROTOZOA						
[illegible] na						
[illegible] sp.						
[illegible] pyriformis						
[illegible] globula						
[illegible] aculeata					200	
[illegible]phora						
[illegible]trochus sp.						
[illegible]						
[illegible]ella fatella				400		
[illegible] sp.*						200
[illegible] sp.						
[illegible]morphorus sp.						
[illegible] [illegible]ularis*						
[illegible]						
[illegible]oda spp.						
[illegible]						
[illegible]ifera sp.					200	
[illegible]						
[illegible]hnia sp.*						
Total Living Organisms	132,600	157,500	131,000	270,400	252,200	88,400

sp. - 1 undetermined species.
spp. - 2 or more undetermined species.
gr. - Group of species or closely related genera not identifiable at magnification used.
Underlined numbers indicate dead organisms.

Numbers per liter at each station (cont'd.)

	Sta. 3 Yellow-stone River	Sta. 4 Yellow-stone River	Sta. 5 Yellow-stone River	Sta. 6 Big Horn River	Sta. 7 Yellow-stone River	Sta. 8 Yellow-stone River	Sta. 9 Powder River	Sta. 10 Yellow-stone River	Sta. 11 Yellow-stone River
							200		
								400	
								600	
			200						
					200				
		400							
				200					
						200			
						200			
								200	200
						200			
			200						
								200	
0	131,000	270,400	252,200	88,400	82,000	146,800	[illegible],800	114,600	166,200

enera not identifiable at magnification used for courting.
nisms.

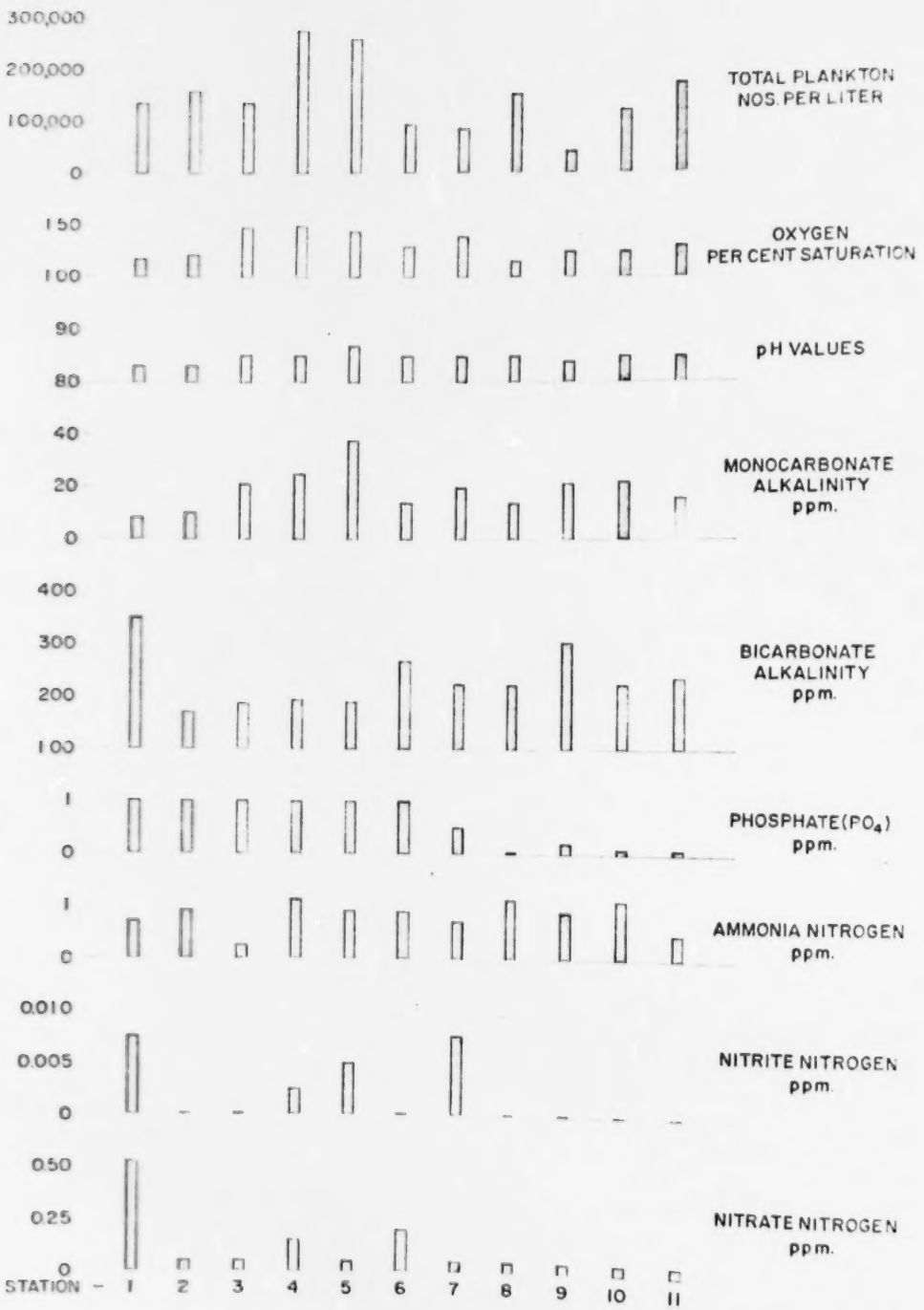
introduction into the Yellowstone and in some instances even increased their density (see Asterionella and Fragilaria, Table 5).

August plankton concentrations were considerably greater than those occurring in September, but photosynthetic effects upon water chemistry were not noticeably more marked. Yellowstone River plankton and chemical features in this respect confirm experiments that have shown there is no definite relationship between number of photosynthetic organisms (or chlorophyll concentration) and rate of photosynthesis after certain levels are reached.

Discussion

Entrance of organic pollution was chemically detectable but nowhere did it greatly impair domestic water quality at the times of this investigation. Some large role in abatement of pollutional effects must be ascribed to life processes of benthic and plankton algae, as their influences upon stream chemistry were quite marked. It appears safe to assume that photosynthetic modifications of water chemistry characterize the Yellowstone throughout periods of low clear stages in summer and fall.

Figure 5 shows water chemistry and plankton densities (total living organisms) observed in September. Photosynthetic intensity varies with time of day, and a greater algal concentration, after certain levels are reached, does not always result in increased photosynthesis. Activities of benthic algae also influenced water chemistry, and their concentration at various localities was not estimated. Organisms in the plankton should be regarded as only a portion of the biota that affected water chemistry. Greater plankton density in the first several miles below Billings was due to increased concentration of displaced benthic forms and a greater total



YELLOWSTONE RIVER
PLANKTON AND CHEMICAL VARIATIONS
SEPTEMBER 23-25, 1952

algal crop was likely responsible for higher pH and monocarbonate levels attained in that stretch. Algal increase in this area was coincident with entrance of wastes that augmented nitrite and nitrate content of water.

Significant quantities of phosphate, present in all stream reaches sampled in August, and at all except one locality sampled in September, hardly appear due to pollution alone. A suspicion exists that PO_4 arises, partly at least, from underground formations that drain to long stretches of streams. Phosphate formations have been described for the Yellowstone Park region. While pollution presumably augments PO_4 in some localities, it seems unlikely that phosphate from separate, widely scattered sources of pollution would be able to persist over long stream stretches in the face of its consumption by abundant algal growths. Occurrence of phosphate over such long river reaches is exceptional, and no doubt plays an important role in maintenance of considerable algal concentrations when physical conditions, turbidity, etc., favor their growth.

Oil refinery wastes appeared responsible for elimination of bottom fauna from at least 11 miles of the Yellowstone below Billings. Heavy oily or tarry compounds that settle to the bottom are largely responsible for this state of affairs, which is deleterious to the fishery in that segment of the river. Direct effects of refinery wastes upon fishes were not observed as study of fishes was considered unimportant in taste and odor work.

Wastes discharged at Hardin, Billings, or other municipalities unquestionably induce or aggravate taste and odor problems under proper conditions. Such wastes may stimulate algal growths or be obnoxious themselves. Water works operators indicated that a taste and odor problem

reported in 1951 was present only below the mouth of the Big Horn. The sugar beet refinery at Hardin was suspected of being the cause of the taste and odor problem, but no definite evidence was obtained. In August and September, 1952, the Big Horn introduced certain phytoplankters into the Yellowstone in which their density either increased or remained fairly great. It is entirely possible that a similar occurrence with initially greater plankton densities brought about water quality problems in 1951. No definite description of the 1951 taste or odor was gleaned from discussions with water works personnel, and it is not possible to indicate either wastes or algal growths as its source.

Algal upsets or die offs resulting from slug releases of toxic wastes may also result in water supply problems as reported in 1951. Under such conditions algal chemical influences would play no role in pollutional abatement and concentration of dead bottom fora could increase to nuisance levels in the plankton.

Only speculative remarks concerning causes of taste and odor problems are permissible at this time, and limnological studies during a season of their occurrence are indicated.